Humidity (Psychrometric) Chart

One may ask, why should we bother to learn how to read a psychrometric chart? After all, we have myriad online calculators, tables, iPhone apps, etc. Most of our instruments perform the conversions as a built in feature. From a web sides prepared by Rotronic, I show you humidity chart using methods. The first step in making a better measurement is to understand the parameter you wish to measure. What better way to begin to understand the various humidity parameters and their interrelations than to study the visual representation in a psychrometric chart.

**Humid air**: Moist air, there is water vapor and DA.

**Humid volume**: Volume of 1 kg (or lb) DA plus water vapor in the air.

\[
\frac{\text{m}^3}{\text{kg DA}} = \frac{22.415 \text{ m}^3 \text{ kg mol DA}}{29 \text{ kg DA}} + \frac{22.415 \text{ m}^3 \text{ kg mol H}_2\text{O}}{18 \text{ kg H}_2\text{O}} \left( \frac{\text{H kgH}_2\text{O}}{\text{kg DA}} \right)
\]

\[
\frac{\text{ft}^3}{\text{lb DA}} = \frac{359 \text{ m}^3 \text{ lb mol DA}}{29 \text{ lb DA}} + \frac{359 \text{ m}^3 \text{ lb mol H}_2\text{O}}{18 \text{ lb H}_2\text{O}} \left( \frac{\text{H kgH}_2\text{O}}{\text{kg DA}} \right)
\]

**Humid heat**:

\[
\frac{\text{kJ}}{\text{kg DA}} = \frac{\text{kJ DA}}{\text{kg DA}} + \frac{\text{kJ H}_2\text{O}}{\text{kg H}_2\text{O}} \left( \frac{\text{H kgH}_2\text{O}}{\text{kg DA}} \right)
\]

**Dry bulb temperature** (T<sub>DB</sub>): is the ordinary temperature you always have been using for a gas in °C or °F (or °R or K).

**Wet bulb temperature** (T<sub>WB</sub>): something new. As you may guess, even though you may never have heard of this T<sub>WB</sub> before, it has something to do with water (or other liquid, if we are concerned not with humidity but with saturation) evaporating from around an ordinary mercury thermometer bulb. Suppose that you put a wick or porous cotton cloth placed around the mercury bulb of a
thermometer and think they are wet. Next you either (1) whirl the thermometer in the as in Figure 29.1 (this apparatus is a sling psychrometer when a wetbulb and a dry-bulb thennometer are both mounted together), or (2) set up a fan to blow rapidly on the bulb a high linear velocity. What happens to temperature recorded by the wet-bulb thermometer? Temperature starts to decrease and reaches an equilibrium, $T_{\text{sat}}$, which is known as $T_{\text{WB}}$. **Now system reaches fullyy saturation and 100%RH.**

Dew point temperature ($T_{\text{dp}}$): is a T below which water vapor will condense out of air. Air that is holding as much water vapor as possible is saturated or at its dew point. Water will condense on a surface such as building wall or window that is at or below the dew point T of the air.

Tips and tricks for the psychrometric chart. As long as you have any 2 parameters where the lines will cross each other, you can determine all other parameters (Seven parameters, $T_{\text{Db}}, T_{\text{WB}}, T_{\text{dp}}, \text{RH}, \dot{V}, \Delta H$ (and correction for $\delta \dot{H}$) and $\dot{H}$).
For example, let’s say you know the dry bulb temperature is 70°F and the dew point is 50°F. Take a ruler and draw a vertical line at the dry bulb temperature of 70 and draw a horizontal line where the dew point is 50. Find the state point and you can read the relative humidity, wet bulb, enthalpy, vapor pressure and humidity ratio. As another example, let’s say you know that the wet bulb temperature is 50 and the dry bulb temperature is 75. Plot the state point and read the rest of the parameters.

If you want to know the cooling effect of an evaporative cooler, plot the state point where the dry bulb temperature line and the wet bulb temperature line intersect or you could plot the point where the dry bulb temperature and the relative humidity intersect. Follow the wet bulb line all the way to the saturation curve. Then read the dry bulb temperature at that saturation point. The difference between the temperature at the original point and the final point is your effective cooling of the air.

I suggest taking some time to get familiar with the chart. Knowing the psychrometric chart will help you understand the humidity parameters and their interrelations leading to a better measurement of humidity.

**Example 1:** Air is at 25C and **T_WB** is 20C, find all possible properties
Sensible heating or cooling: A psychrometric process that involves the increase or decrease in temperature of air without changing humidity (Ex: passing humid air over a room space heater and kiln air over the heating coils)

Pink colored arrow shows heating, opposite direction will be for cooling

Example: The system at 60°C and $T_{WB}$ 50°C is heated to 70°C, find final $T_{WB}$ and RH.
A psychrometric process can involve the simultaneous increase in both $T_{DP}$ and $H$ of the air.
A psychrometric process can involve the removal of water from the air as the air temperature falls below $T_{dp}$.

Adiabatic cooling

A psychrometric process can involve cooling of air without heat loss or gain. Sensible heat lost by the air is converted to latent heat in the added water vapor.

Self-assessment questions from Himmelblau books

1. Air at a dry-bulb temperature of 200°F has a humidity of 0.20 mol $H_2O$/mol dry air. (a) What is its dew point? (b) If the air is cooled to 150°F, what is its dew point?

2. Air at a dry-bulb temperature of 71°C has a wet-bulb temperature of 52°C. (a) What is its percentage relative humidity? (b) If this air is passed through a washer-cooler, what would be the lowest temperature to which the air could be cooled without using refrigerated water?

3. Estimate for air at 70°C dry-bulb temperature, 1 atm, and 15% relative humidity: (a) kg $H_2O$/kg of dry air, (b) m$^3$/kg of dry air, (c) wet-bulb temperature (in °C), (d) specific enthalpy, and (e) dew point (in °C).

4. Calculate the following properties of moist air at 1 atm and compare with values read from the humidity chart.
   (a) The humidity of saturated air at 120°F.
   (b) The enthalpy of air in part (a) per pound of dry air.
   (c) The volume per pound of dry air of the air in part (a).
   (d) The humidity of air at 160°F with a wet-bulb temperature of 120°F.
29.1 Autumn air in the deserts of the southwestern United States during the day will typically be moderately hot and dry. If a dry-bulb temperature of 27°C and a wet-bulb temperature of 17°C is measured for the air at noon: (a) What is the dew point? (b) What is the percent relative humidity? (c) What is the humidity?

29.2 Calculate:
(a) The humidity of air saturated at 120°F
(b) The saturated volume at 120°F
(c) The humid heat.

29.3 Give expressions and/or definitions for the following:
(a) saturated air
(b) percentage humidity
(c) humid heat
(d) humid volume
(e) saturated volume
(f) dew point

29.4 Urea is produced in cells as a product of protein metabolism. From the cells it flows through the circulatory system, is extracted in the kidneys, and excreted in the urine. In an experiment the urea was separated from the urine using ethyl alcohol, and dried in a steam of carbon dioxide. The gas analysis at 40°C and 100 kPa was 10% alcohol by volume and the rest carbon dioxide. Determine the following:
a. The grams of alcohol per gram of CO₂.
b. The percent relative saturation.
c. The humid heat.
d. The humid volume.
e. What the humid volume would be if the CO₂ were saturated with alcohol.

29.5 What is the difference between the constant enthalpy and constant wet bulb temperature lines on the humidity chart?

29.6 Under what conditions are the dry bulb, wet bulb, and dew point temperatures equal?

29.7 Explain how you locate the dew point on a humidity chart for a given state of moist air.

29.8 Under what conditions can the dry bulb and wet bulb temperatures be equal?

29.9 What does a home air conditioning unit do besides cooling the air in the house?

29.10 Under what conditions are the adiabatic saturation temperature and the wet bulb temperature the same?

29.11 Why is a process of just heating or cooling of moist air represented as a horizontal line on the humidity chart?

29.12 Moist air has a humidity of 0.020 kg of H₂O/kg of air. The humid volume is 0.90 m³/kg of air.
(a) What is the dew point?
(b) What is the percent relative humidity?
29.13 Moist air at 100 kPa, a dry-bulb temperature of 90°C, and a wet-bulb temperature of 46°C is enclosed in a rigid container. The container and its contents are cooled to 43°C.
(a) What is the molar humidity of the cooled moist air?
(b) What is the final total pressure in atm in the container?
(c) What is the dew point in °C of the cooled moist air?

29.14 Use the humidity chart to estimate the kg of water vapor per kg of dry air when the dry bulb temperature is 30°C, and the relative humidity is 65%.

29.15 For air at an atmospheric pressure of 14.7 psia, a dry bulb temperature of 82°F, and a wet bulb temperature of 70°F, determine from the humidity chart:
   a. The humidity
   b. The relative humidity
   c. The vapor pressure of water at 82°F in psia and the pressure of the water vapor
   d. The dew point
   e. The enthalpy
   f. The specific volume per pound of dry air

29.16 Humid air at 1 atm has a dry-bulb temperature of 180°F and a wet-bulb temperature of 120°F. The air is then cooled at 1 atm to a dry-bulb temperature of 115°F. Calculate the enthalpy change per lb of dry air.

29.17 What are the pounds of water vapor per pound of dry air when the dry bulb temperature is 80°F and the relative humidity is 65%.

29.18 What are the humidity, wet bulb temperature, humid volume, dew point, and specific enthalpy of air at 35°C and a relative humidity of 30%.

29.19 What are the relative humidity and specific enthalpy of air that has a dry bulb temperature of 40°C and a wet bulb temperature of 25°C.

29.20 What are the dry bulb temperature, wet bulb temperature, relative humidity humid volume, and enthalpy of air that has an absolute humidity of 0.02 kg/kg dry air and an enthalpy at saturation of 85.1 kJ/kg dry air.

29.21 The air supply for a dryer has a dry-bulb temperature of 32°C and a wet-bulb temperature of 25.5°C. It is heated to 90°C by coils and blown into the dryer. In the dryer, it cools along an adiabatic cooling line as it picks up moisture from the dehydrating material and leaves the dryer fully saturated.
(a) What is the dew point of the initial air?
(b) What is its humidity?
(c) What is its percent relative humidity?
(d) How much heat is needed to heat 100 m³ of initial air to 90°C?
(e) How much water will be evaporated per 100 m³ of air entering the dryer?
(f) At what temperature does the air leave the dryer?

29.22 Calculate:
(a) The humidity of air saturated at 120°F
(b) The saturated volume at 120°F
(c) The adiabatic saturation temperature and wet-bulb temperature of air having a dry-bulb 7° = 120°F and a dew point = 60°F
(d) The percent saturation when the air in (c) is cooled to 82°F
(e) The pounds of water condensed/100 lb of moist air in (c) when the air is cooled
to 40°F

29.23 What is the lowest temperature that air can attain in an evaporative cooler if it enters
at 1 atm, 29°C, and 40 percent relative humidity?

29.24 In heating and cooling systems, why is heated air sometimes humidified?

29.25 Why is cooled air in an air conditioning system sometimes reheated before discharging
the air into a building?

29.26 On the humidity chart, does the adiabatic mixing of two airstreams yield a state for the
mixture that has to be on the straight line connecting the states of the two streams?

29.27 A rotary dryer operating at atmospheric pressure dries 10 tons/day of wet grain at
70°F, from a moisture content of 10% to 1% moisture. The air flow is countercurrent
to the flow of grain, enters at 225°F dry-bulb and 110°F wet-bulb temperature, and
leaves at 125°F dry-bulb. See Fig. P29.27. Determine:
(a) The humidity of the entering and leaving air if the latter is saturated
(b) The water removal in pounds per hour
(c) The daily product output in pounds per day
(d) The heat input to the dryer
Assume that there is no heat loss from the dryer, that the grain is discharged at 110°F,
and that its specific heat is 0.18.

![Figure P29.27](image)

**29.31** Air, dry-bulb 38°C, wet-bulb 27°C, is scrubbed with water to remove dust. The water
is maintained at 24°C. Assume that the time of contact is sufficient to reach complete
equilibrium between air and water. The air is then heated to 93°C by passing it over
steam coils. It is then used in an adiabatic rotary drier from which it issues at 49°C. It
may be assumed that the material to be dried enters and leaves at 46°C. The material
loses 0.05 kg H₂O per kilogram of product. The total product is 1000 kg/hr.
(a) What is the humidity:
(1) Of the initial air?
(2) After the water sprays?
(3) After reheating?
(4) Leaving the drier?
(b) What is the percent humidity at each of the points in part (a)?
(c) What is the total weight of dry air used per hour?
(d) What is the total volume of air leaving the drier?
(e) What is the total amount of heat supplied to the cycle in joules per hour?
The given psychrometric chart below has been marked with several points from 1-9. Each point represents some specific point or curve or a line.

Specify each point represents what?

P1. (a) 133°F; (b) the same
P2. (a) 40%; (b) 52°C
P3. (a) 0.03 kg/kg dry air; (b) 1.02 m³/kg dry air; (c) 38°C; (d) 151 kJ/kg dry air; (e) 31.5°C
P4. (a) $\dot{H} = 0.0808 \text{ lb H}_2\text{O}/\text{lb dry air}$; (b) $H = 118.9 \text{ Btu/lb dry air}$; (c) $V = 16.7 \text{ ft}^3/\text{lb dry air}$; (d) $\dot{H} = 0.0710 \text{ lb H}_2\text{O}/\text{lb dry air}$

Chapter 29

29.1 (a) 10°C; (b) 38%; (c) 0.79 kg H₂O/kg air
29.4 (a) 0.116 g A/g C; (b) 55.9%; (c) 1.22 J/(K)(g C); (d) 0.877 m³/kg C; (e) 0.878 m³/kg C
29.8 At 100% relative humidity (saturated air)
29.12 (a) 27°C; (b) 57%